Dynamic Psychophysics and the Phi Phenomenon

BY

G. M. GILBERT, Ph.D.

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CHAPTER I

INTRODUCTION

Static and Dynamic Psychophysics

Modern psychophysics has produced overwhelming evidence of the inadequacy of the traditional static relationship between stimulus and response, wherein each attribute of a sensory response was conceived of as determined simply by the value of a corresponding physical dimension of the "adequate" stimulus. Actual experimental evidence (some of it, to be sure, dating from the earliest psychophysical experiments) has shown that the dimensions of stimulation are interdependent in affecting a sensory response, and that sensation may be dependent on the interaction of excitations, on mental set, physiological state of the organism, practice, and numerous other factors, all interrelated and in a constant state of flux. In addition, Gestalt psychology has shown that perception requires the study of field properties which are not readily induced from the analysis of stimulus dimensions. The development of psychophysical systems from the static to the more dynamic, or from the over-simplified and artificial to the more complete and realistic, is worthy of consideration at much greater length than we are prepared to go into it at this time, and will be the subject of another paper. Our purpose in this study is to consider by specific example the kind of problem toward which the modern trend in psychophysics seems to be directed; namely, the quantitative formulation of *perceptual processes* rather than equations between attributes of sensation and corresponding dimensions of adequate stimuli. Before describing the scope of the present study, a word about the phenomenon selected for experimentation.

The Phi Phenomenon

The theoretical significance of apparent visual movement, commonly called the "phi phenomenon" after Wertheimer's description, has been a bone of contention among sensory theorists for over sixty years. Exner used it to support his distinction between perception and sensation; Stern, to illustrate conscious and unconscious inference in perception. Marbe explained the phenomenon on the basis of a Wundtian concept of the range and fluctuation of attention (*unbemerkte Phasenausfall*), and Benussi, on the basis of Witasek's concept of *Vorstellungsproducktion.* In the hands of

Wertheimer, Koffka, and Köhler it became one of the chief experimental cornerstones of *Gestalttheorie,* and appears to have remained very largely Gestalt property ever since, in spite of Titchener's and Madison Bentley's attempts to analyze the *Gestaltqualität* out of it. For reviews of the experimental and theoretical literature on the phenomenon of apparent movement we refer the reader to monographs written independently by Neff (5) and Hovland (3).

Our interest in the phi phenomenon is purely to illustrate what we conceive of as the dynamic approach to psychophysics. Nevertheless, a consideration of the stimulus-response relationship is necessary as a starting point or frame of reference for this investigation;—a significant point in itself. This relationship is probably best expressed by the Korte-Koffka formulations.

Koffka (4) summarized Korte's laws as follows:

> Let us assume that the process may be measured by a quantity ϕ whose properties are such that $\phi_{sim.} > \phi_{opt.} > \phi_{suc.}$ Then we may state:[1]
>
> $$\phi = f \frac{d}{i \cdot t}$$
>
> where the nature of the function is still undetermined. The function naturally has its limits of applicability. The range for t may be varied at will, as long as we vary it only by varying e [exposure time]. On the other hand, we approach a limit when we make p [interval between exposures] too large. . . . The range of i lies between a threshold value and a maximum imposed by blinding light. . . . The range of d has an upper limit. If the distance between the two objects is too great, then movement may no longer be perceived. . . . If d becomes very small, the movement may be perceived more and more readily. . . .

The sum and substance of this formulation is that ϕ is a quantity varying directly with distance and inversely with time and intensity, within certain limits, and that it should be possible empirically to determine values for ϕ which will give apparently simultaneous exposure, a smaller value which will give apparent movement, and a still smaller value which will give alternation or succession;—allowance being made, of course, for individual differences, etc.

The formula summarizes the facts as well as can be done in terms of stimulus dimensions. We may regard it as furnishing a basis for approximate prediction of the probable distribution of judgments with each of the named dimensions as the independent variable. Thus, if t is increased from minimum to maximum:

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[1] The original formula is $\phi = \frac{s}{i, g}$. We merely substitute the English equivalents: d = distance, i = intensity, t = time, or duration of cycle.

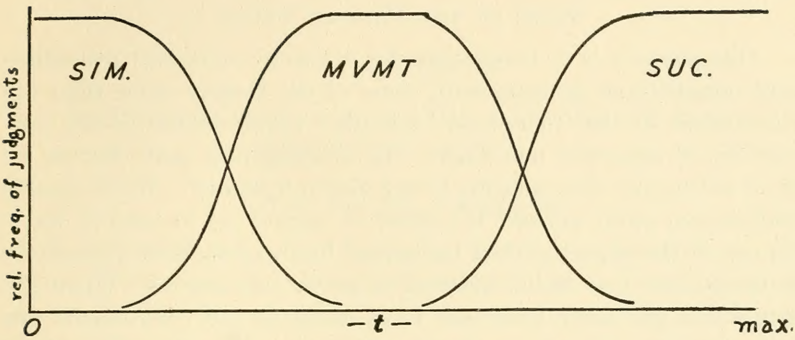

FIG. 1

The inadequacy of formulation of perceptual experience in terms of stimulus dimensions has led to an unfortunate misconception of the Gestalt psychologists' approach to the problem, as exemplified by the following statements by Neff:

> Their analysis of the stimulus factors has been fruitful and suggestive. . . . But there are other variables on the side of the organism which require much more extensive investigation before we can say that our experimental study of this performance is nearing completion. The configurationists' emphasis upon the stimulus . . . has led them to substitute another "constancy hypothesis" for the older theory, against which they successfully polemicized during the early years of the school.

This attack is entirely unjustified. Both Wertheimer and Koffka have implicitly and explicitly emphasized the importance of mental set, practice, and other organic variables which influence the response (*cf.* 7, p. 209; 4, p. 1187).

In attacking Korte's laws, Neff also states: "The time has not yet come to formulate 'laws,' even if we qualify them by the saving phrase 'all other conditions remaining constant.' "

Here again we wish to take exception and raise a fundamental issue in what we have described as the dynamic orientation in psychophysics. If accounting for all the extra-stimulus variables is necessary before psychophysical formulations are justified, then the time will never come. On the contrary, an understanding of the stimulus functions with their recognized limits of applicability as described above, for example, serves as a most convenient frame of reference for the quantitative investigation of the extra-stimulus variables, which is the essence of a dynamic orientation in psychophysics and makes possible a more complete formulation of perceptual processes. Such, at least, is the position taken in this investigation.

Scope of the Present Study

Our purpose is to investigate, by properly controlled procedure and quantitative measurement, some of the factors other than the dimensions of the "adequate" stimulus which determine the perception of apparent movement. In investigating such factors we shall not by any means be exploring virgin territory. Wertheimer's well-known study showed the effect of mental set in various ways. In one of the experiments a horizontal line was exposed alternately with another line which bisected it at various angles. When the angle was gradually increased to as much as 120°, movement was still seen over the obtuse angle, although under other conditions the acute angle was preferred. This is a simple illustration of what might be called perseveratory set. Instructions to vary the concentration of attention without changing fixation also produced great variations in the response. De Silva's study (1) contains data on the effect of practice. In general, the quality of movement produced by a constant stimulus improves at first, but eventually deteriorates. A passive attitude was found to facilitate movement, while an actively discriminating attitude inhibited it. Zietz and Werner (8) reported qualitative observations on the effect of auditory rhythms on apparent movement. Sounds presented simultaneously with the lights facilitated movement, whereas irregular rhythms tended to inhibit it. There are few well-controlled studies of this sort, however, and quantitative data are lacking for the most part.

Three experiments have been designed with a view to executing our purpose. Experiment 1 will attempt to follow the temporal course of the function with nothing but repeated stimulation and the time interval between sessions as variables. Experiments 2 and 3 are designed to investigate more thoroughly than has been done heretofore the interdependence of the senses,—as yet a little-recognized illustration of the interaction of excitations. No special experiment is designed to examine the influence of mental set, an influence already well established, but experiment 1 will furnish some supplementary data of relevance.

CHAPTER II

EXPERIMENT 1.—TEMPORAL COURSE OF THE PHI PHENOMENON

Apparatus and Procedure

It is evident from Fig. 1 (p. 7) that the range of temporal values for apparent movement determines all three components of the graph, since simultaneity is represented by all values below a given range of t, and succession by all values above this range. Under conditions of continuous stimulation, therefore, the range of stimulus-frequencies within which apparent movement may be observed serves as a convenient measure of the entire function. With the stimulus situation held constant, it is proposed to determine what changes, if any, take place during four one-hour sessions of observation, held at different intervals of succession. For this purpose 10 observers were paired as follows:

- 2 O's—4 successive hours, with only 10-min. rest periods between sessions.
- 2 O's—4 sessions at 12-hour intervals, 1 starting at 9 A.M., the other at 9 P.M.
- 2 O's—4 sessions on consecutive days, at the same hour every day.
- 2 O's—4 sessions with intervals of 3 to 10 days between them.
- 2 O's—4 sessions at mixed intervals from immediate succession up to 103 days.

In addition to the above sequences, it was possible to observe the temporal course of the function during each of the experimental sessions as well as during each of the trials in each session.

O was seated in a relatively sound-proof and light-proof chamber, and all stimuli were given by the experimenter through remote control. E was seated outside the chamber during all sessions, operating the controls (Fig. 2). O's task was to observe the visual stimuli which consisted of two alternately-presented $1\frac{1}{2}$-inch circular patches of light on a milk-glass panel, illuminated from behind by neon bulbs in tubes. The patches were $3\frac{3}{4}$ inches apart from center to center, and O was seated 5 feet from the panel. He was instructed to distinguish at all times among the three phenomenal stages: (1) alternation, (2) movement, (3) simultaneity. His responses were communicated to E by means of a signal system. Four telegraphic signal keys were mounted on a board before O,

and these were connected by means of a cable running through the chamber wall to four differently colored flashlight bulbs mounted on a board before E, directly beneath the tachometer dial which gave the frequency readings. The first key and the corresponding bulb indicated observed alternation; the second, movement; the third, simultaneity. The fourth key served merely as an emergency signal to insure proper functioning of the apparatus during the experimental sessions.

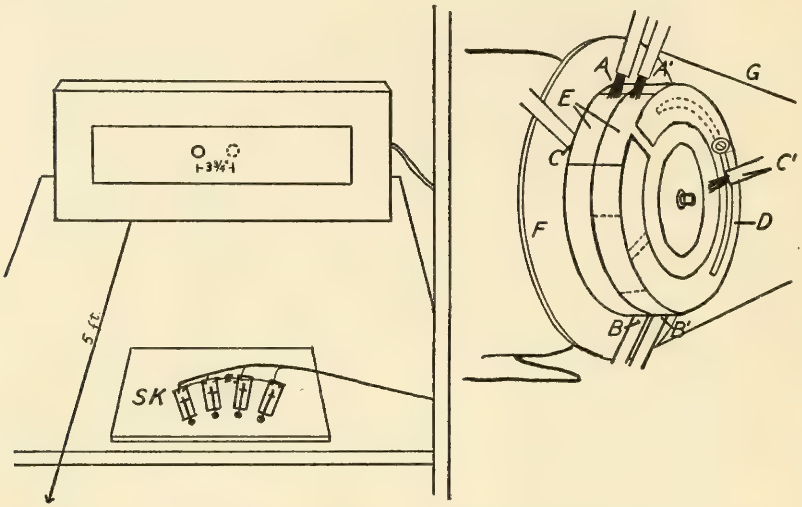

FIG. 2. *Left:* Setup in darkroom. Alternating lights on panel of box observed by O, who reports response by means of signal keys, SK. *Right:* Stimulus control in adjoining room. Brushes A and B (180° apart) close circuit for left and right lights with C as common. A′, B′, and C′ close circuit for auxiliary stimulus (not used in experiment 1). D is 90° slot permitting change in relative position of outer disk, as indicated by dotted lines, causing alternate instead of simultaneous contact of two 60° sectors, E, at brushes. Flywheel, F, is connected to tachometer by means of pulley, G, so that speed of revolution of commutators may be recorded as ∼/min. of stimulation.

The current line to the neon lights was intercepted by a specially designed commutator attached to the motor spindle, as shown in Fig. 2. The revolving contact sector alternately closed the circuits for the left and right lights. Since the sector was 60° and the brushes were 180° apart, the duration of each stimulus was $\frac{1}{6}$ of the cycle, and the interval following each stimulus $\frac{1}{3}$ of the cycle. The tachometer indicated the r.p.m. of the motor, which corresponded exactly to the ∼/min. of the stimuli. The rate of stimulus-frequency was slowly increased and decreased for each trial by means of the potentiometer, thus giving an ascending and descending

series of stimulus-frequencies. E recorded the $\sim$/min. of stimulation at the moment the signal shifted from alternation to movement, and from movement to simultaneity, as well as all reversals of response. E occasionally introduced, "off-the-record," test reversals in the direction of change of frequency during the ascending and descending series to insure alertness of O, and to prevent him from responding merely by any fixed routine. The rate of ascent and descent was not always exactly the same, although an accurate reading of the tachometer dial required a rather slow rate of change at all times, and the complete range of frequencies (0–300 $\sim$/min.) was not always covered.

The range of frequencies over which apparent movement was observed for each ascending and descending series constituted the reading for each series. The mean of an ascending and descending series was used as the range-value for the trial. There were 12 trials in each session, and 48 altogether for each O. A 15-minute practice period preceded the first session. There was a ½-minute rest between trials, and a 5-minute rest after the 6th trial. One practice trial was given again at the beginning of each subsequent session.

Reversals of response at the phi-simultaneity threshold were quite frequent with most O's. While observing the lights in the ascending series of frequencies, for example, O would shift the movement signal to the simultaneity signal at a certain point, and then some time after this point had been passed would signal movement again for a brief interval;—then simultaneity again, and then back to movement,—with the frequency of stimulation *increasing* all the time. Sometimes there were as many as 8 or 10 reversals in a single series. This was definitely established to be an actual fluctuation of response, or ambiguity of perceptual integration, rather than the effect of the test reversals, or of uncertainty of response. Actual "off-the-record" reversals of stimulation were not given where O spontaneously gave frequent reversals of response. All O's were unanimous in reporting that the distinction between stages 2 and 3 was easy to make, even though the distinction between 1 and 2 was not always so clear-cut. The fluctuation between simultaneity and movement was quite unmistakable, and the stimulus at the proper frequency may be regarded as an ambiguous figure in much the same sense as ambiguous figure drawings.

As a check on the actual ambiguity of this configuration a frequency rate was selected within the range of frequencies where such

ambiguity generally occurred,—usually 200 ~/min. This constant stimulus was presented to O at the end of each session for 60 sec. and his responses recorded. The reversals obtained by the method of limits as well as by use of the constant stimulus are included in Table 1.

The ranges of the reversals were added to the main range for apparent movement, to give the value used as a measure of the phi function for that trial. For example:

	alt.-mvmt.	*mvmt.-sim.*	*reversals*	*range*	*mean*
asc. →	90	190	210–220, 240–245 ϕ	115	112.5
desc. ←	80	200	180–170 sim.	110	

RESULTS

The results of experiment 1 are given graphically in Figs. 3–5, and the data showing ambiguity in Table 1.

One characteristic of the phi function which stands out immediately upon inspection of the curves is the violent fluctuation of the values obtained during most of the sessions. This is not merely an artifact of the scale used in the graphs. It will be observed that the range of frequencies obtained for apparent movement on one trial often jumps to twice or triple that value on the very next trial, and soon drops back again to a very low value, only to rise again. At times the fluctuation appears to take on a rhythmic character, as in the four-trial "cycle" apparent in B.G.'s 3rd session, or the apparent five-or-six-trial "cycle" which is roughly evident throughout F.B.'s curve. We hesitate, however, to draw the conclusion that there is a definite rhythmic fluctuation of the psychophysical function, since even "chance" fluctuations will occasionally take on a rhythmic appearance. At other times, as may be observed during the 2nd and 3rd sessions for C.S., the range values are high at the beginning of the session, and drop to O or close to it before the end of the session. This means that whereas apparent movement is observed over a wide range of frequencies on one trial—let us say from about 100 ~/min. to 170 ~/min., which gives a range value of 70 ~/min. (trial 26) apparent movement is *not observable at all* on another trial, either in the ascending or descending series, so that the range value for that trial (32) is O.

Such gross deviations of response can hardly be explained on the basis of "errors of observation," nor can they be attributed to occasional lapses of attention on the part of some observers. Even the extreme cases of a O value on either the ascending or descending

series or both on a given trial occurred several times in all three experiments in this study, and all O's reported a high degree of confidence in their reports at all times, as well as responding satisfactorily to the off-the-record reversals.

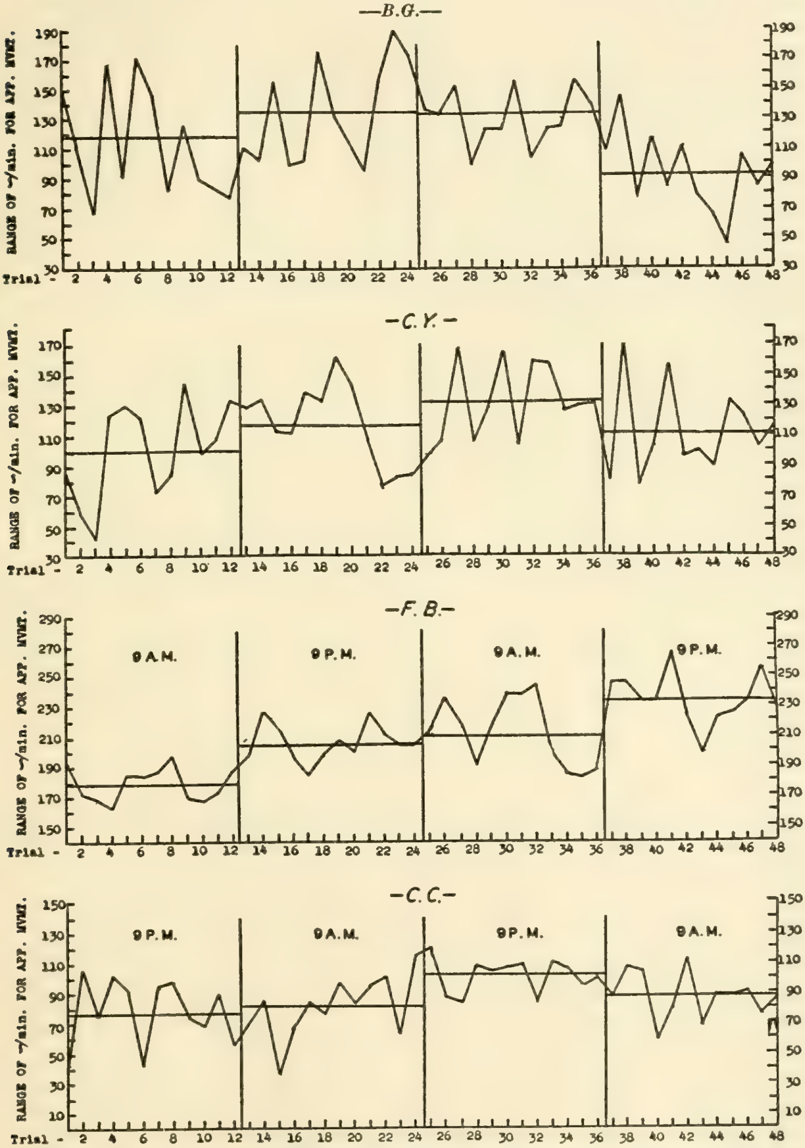

FIG. 3. Temporal course of the frequency-range for apparent movement. B.G. and C.Y. received four consecutive hours of stimulation; F.B. and C.C. four hours at 12-hour intervals.

In addition to, and in spite of momentary fluctuations, there is evidence of *progressive* changes in the phi function, in the nature of practice and fatigue effects. If we compare the mean for each succeeding session (horizontal line) in Fig. 3, we observe a general increase in the range for at least the first three sessions. In the case of B.G. there is a rise in the level of range values from the 1st hour to the 2nd, which is maintained during the 3rd hour, and a drop during the 4th to below the level of the 1st. In the case of C.Y. there is a progressive rise in the level of range values from the 1st to the 3rd hour, and then a drop to almost the level of the 1st. These results may readily be interpreted as showing the combined influence of positive and negative adaptation, or practice and fatigue effects. The practice effect is evident during the first three consecutive hours, and the fatigue effect is evident toward the end of the four-hour session.

The fatigue effect would presumably be less marked or absent if the sessions were not consecutive as is the case with F.B. and C.C. This presumption we find to be more or less correct. There is a progressive rise in the mean range from the 1st session to the 4th in the case of F.B., and the 4th session for C.C. is still at a slightly higher level than the 1st two sessions, in spite of the drop from the 3rd session level. There is a definite suggestion of a diurnal fluctuation in the adaptation effect. It will be observed that there are 3 substantial rises of the mean in sessions at 12-hour intervals; from sessions 1 to 2 and 3 to 4 for F.B., and from 2 to 3 for C.C. All three of these intervals are A.M.-to-P.M. intervals, and the only such intervals in this experiment. The P.M.-to-A.M. intervals, however, show only very slight increases of range or else a decrease. It appears from this that sessions held on the same day are more apt to show the practice effect than sessions held on different days, even when the time interval between sessions is the same,—or, that the evening is more conducive to a high range for phi than the morning. Just what organic processes are involved here we are not in a position to guess, and in any event such explanation or speculation must wait until the actuality of diurnal fluctuations can be established with a larger number of subjects than was warranted by the scope of this experiment.

Proceeding now to the results obtained on different days (Figs. 4–5) we do not find such consistent adaptation effects as those evident in Fig. 3. To be sure, V.S. shows a progressive rise in the mean range from one session to the next, but D.S. shows the reverse

tendency. Both curves were obtained on four consecutive days,—the same days, as it happened,—under exactly the same stimulus conditions, and there is no apparent reason why the effect should have been in the opposite direction for the two O's. That they

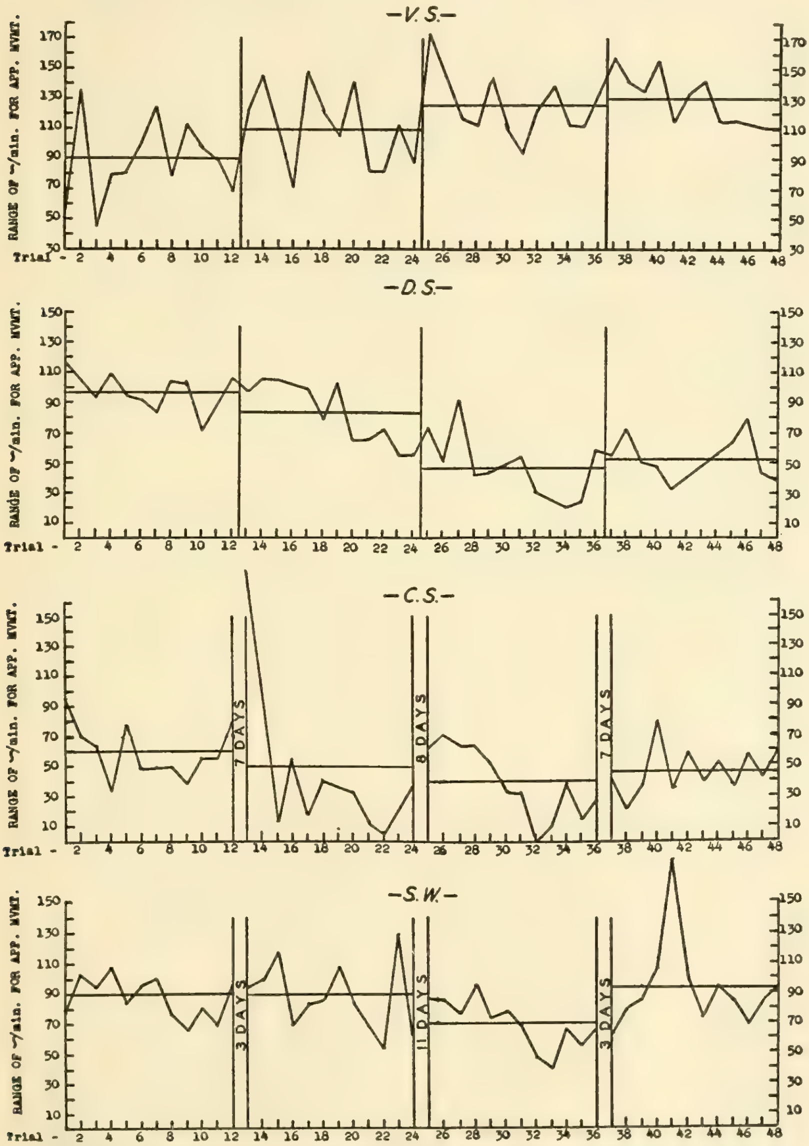

FIG. 4. Temporal course of the frequency-range for apparent movement. V.S. and D.S. received four hours of stimulation on successive days; C.S. and S.W. at the intervals indicated.

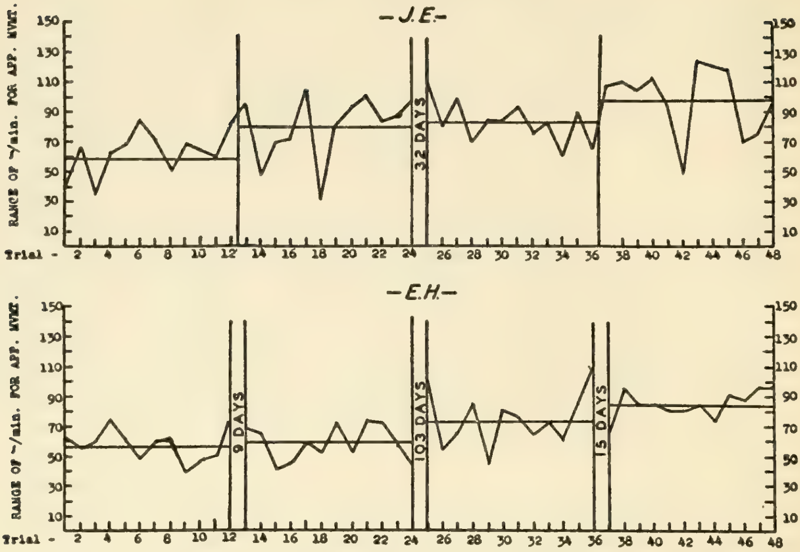

FIG. 5. Two 2-hour sessions for J.E., and four hours for E.H. at intervals indicated.

illustrate the variability of psychophysical functions is quite evident. Intervals of several days between sessions yield even more inconsistent results, as the graphs for C.S. and S.W. show.

Fig. 5 offers little more by way of information on the question whether long intervals between sessions affect the adaptive or experiential factor in the phi function. E.H.'s curve shows that a practice effect may be evident even over long periods of time. J.E., however, affirms the first finding, namely that the practice effect is most likely to occur in the first two (or three) sessions, while showing at the same time that a lapse of about a month shows no appreciable effect. It seems safe to conclude, in general, that the practice effect may be evident in spite of long intervals between sessions, but that it is the rule during the first two or three hours of continued stimulation, while a fatigue effect is the rule during the fourth consecutive hour.

Ambiguity

The number of reversals per trial for 8 O's in experiment 1 is tabulated below both for the ascending and descending series and for the 60 sec. constant stimulus given at the end of each session. It will be noted that in general O's who gave the largest number of reversals in the ascending and descending series gave the largest

number of reversals for the constant stimulus (V.S. & D.S.). Those who gave the fewest reversals in the former gave few or no reversals in the latter (C.C. & C.S.). It is an interesting reflection on the problem of the psychophysical formulation of meaningful Gestalten, to note that exactly the same stimulus yields as many as 21 clear-cut reversals of response in one minute.

TABLE 1

NUMBER OF REVERSALS BETWEEN MOVEMENT AND SIMULTANEITY FOR EACH SESSION

O	*Av. no. reversals per trial (asc. & desc.) by session:*				*~/min. const. stim. 60″*	*No. reversals for 60″ trial at end of each session:*			
	1	*2*	*3*	*4*		*1*	*2*	*3*	*4*
B.G.	2	¼	1	¼	200	8	4	5	1
C.Y.	5	2	½	½	200	10	4	1	3
C.C.	0	0	1½	0	150	5	4	2	1
F.B.	2½	2	2	2	200	7	6	6	6
V.S.	5	7½	6½	6½	200	15	16	16	21
D.S.	5	7	6	7	200	13	13	16	21
C.S.	2	1	1	½	125	0	0	0	0
S.W.	8	4	6	6	200	14	7	11	7

As previously stated, there was a genuine clear-cut shifting of response, not a vacillating uncertainty at a dubious transition-point. O assumed that the stimulus itself was being reversed, as introspections indicate. S.W., for example, remarked during the first rest period: "I notice you're trying to narrow down to see exactly where the change from 2 to 3 takes place." He assumed that after the approximate region of shift had been determined, E was shifting the frequency back and forth within that region to determine the exact point of transition. Actually the stimulation was in a continuous ascending and descending series for each trial. This O was comparatively sophisticated with respect to the nature of the phi phenomenon, and yet had no inkling of the subjective nature of his reversals of response. All the more unsuspecting, therefore, were the more naive O's. At the end of the last session for D.S., when she was shown that there were actually just two lights alternating all the time, and that no reversals of any sort has been given at any time, she exclaimed: "Oh! I feel like such a dope! Here I was watching intently all the time to see which of the three stages you were showing me."

Mental Set

No attempt had been made to introduce mental set as an experimental variable in this series, but there were some interesting manifestations of it just the same.

One of the O's, C.C., was a man of 45 who had been a machine-gunner in the World War. He soon identified the third stage, simultaneity, ". . . like two machine guns,––rat-tat-tat-tat." The persistence of the simultaneity stage was so effective, therefore, that the ambiguous stage was virtually absent, and his upper threshold for phi was much lower on the descending series than on the ascending in almost every trial. In fact, during the first session simultaneity (of the machine-gun fire) was so persistent that no movement was observed at all on the descending series of three of the trials. This accounts for the exceptionally low values on trials 1, 6, and 15 for C.C.

Further evidence of mental set may be found in an inspection of the lower threshold values (alternation-to-phi) on the ascending and descending series in the original data. In some cases there was a distinct tendency to give a lower threshold value on the descending series than on the ascending, an illustration of perseveratory set which has often been reported in psychophysical literature. In one or two cases, however, there was a pronounced tendency in the opposite direction;—a higher threshold value on the descending series than on the ascending, indicating the presence of an anticipatory set. A good illustration of each is found in Fig. 6.

Since these are threshold values rather than the range between two thresholds, a lower value on the descending series indicates perseveration of apparent movement, a higher value on the descending series anticipation of alternation; and vice versa for the ascending series. D.S. shows a distinct anticipatory set until near the end of the experiment; C.S. a more or less consistent perseveratory set. Evidence for anticipatory and perseveratory set is difficult to show at the upper threshold because of the ambiguity effect.

A brief experiment was conducted to check on the possibility that reversals of response interpreted as ambiguity might be the result of reversal habits or a reversal "set" set up by the technique employed, *i.e.,* method of limits. Four naive O's were selected and given training periods of about 15 min. using *constant stimuli* of about 5 sec. duration. A few trials were then given with constant stimuli of about 20 sec. duration, selected to avoid ambiguity as much as possible: *i.e.,* one stimulus (30 ~/min.) which invariably

evoked the alternation response, another (90 ∼/min. or 120 ∼/min.) which was most likely to appear as phi for the given O, and one of the highest frequencies obtainable (290 ∼/min.) which invariably evoked the response of phenomenal simultaneity. Finally, a constant stimulus of 60 sec., duration, either 150 ∼/min.

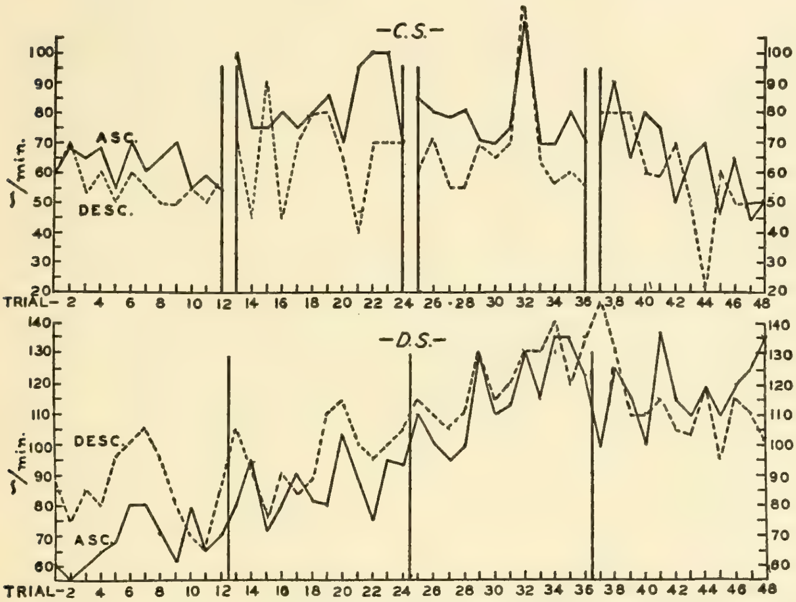

FIG. 6. Anticipatory and perseveratory set as illustrated by difference of the threshold on ascending and descending series.

or 200 ∼/min., selected as most likely to yield ambiguity, was given as in the main experiment. After the record for this stimulus had been obtained, the entire nature of the experiment was revealed to O, to see whether a more sophisticated attitude would succeed in destroying the ambiguity of the constant stimulus. The results are shown in Table 2.

TABLE 2

NUMBER OF REVERSALS FOR 60-SEC. CONSTANT STIMULUS BEFORE AND AFTER EXPLANATION, WITH PREVIOUS TRAINING IN CONSTANT STIMULI ONLY

O	∼/*min.*	*No. reversals*	
		Before	*After*
Dr.	200	22	30
Sa.	150	4	2
He.	150	4	3
Ed.	150	4	2

As is obvious from the above table the ambiguity previously described is not dependent on reversal habits or set established by the presentation routine, nor can it be dispelled by knowledge of the objective nature of the stimulus. That mental set may possibly modify the response, however, is reflected in some of the introspections.

Dr.'s first introspective report after the first 60-sec. constant stimulus was: "First they seemed to move back and forth as one; then they were separate, then one again.—I guess you must have increased the speed to make them look like one." His impression was apparently one of actual movement which simulated simultaneity when the speed of movement was increased. When he was shown that there were actually two stationary lights which alternated at all times, and was told that the last stimulus had not changed speed at all, he showed great surprise and exclaimed: "I could have taken an oath that I saw them move and then change to two stationary flickering lights." After the next trial, in which the number of reversals increased, he said emphatically: "Just couldn't help seeing them first in motion and then as two distinct simultaneous units, even though I know now that it was neither." In his case knowledge of the objective nature of the stimulus apparently set up an anticipatory set for reversal, which increased the number of reversals.

He., however, reported after the last trial: "Knowing that there was no change, I was careful to check my reactions before I responded." This may be interpreted either as the establishment of a perseveratory set or merely a reluctance to report reversal.

The most interesting observation on the possibility of the modification of phi by mental set was made by another observer in a preliminary experiment. She claimed that the reversals were subject to voluntary control, making it possible to see "four beats phi, four beats flicker, and so on,—or any rate of reversal."

Summary

Using the range of stimulus-frequencies for apparent movement as a measure of the phi function, all other stimulus conditions being held constant, the temporal course of this function was recorded for 10 observers during 4 one-hour sessions held at different intervals. The assumption of a constant or static relationship between stimulus and response would require stable values under these conditions. However, the modifying effect of continued experience was manifested by:

1. *Violent momentary fluctuations,* such that apparent movement was entirely or almost entirely absent on some trials, while covering a wide range of frequencies on others, in the same session for the same observer.

2. *Practice and fatigue effects,* the former being more pronounced during the first three consecutive hours of observation, the latter on the fourth consecutive hour.

3. *Ambiguity* of stimulus-response relationship at the phi-simultaneity threshold, even with a constant stimulus.

4. *Mental set* as evidenced by anticipatory and perseveratory tendencies in the ascending and descending series.

CHAPTER III

EXPERIMENT 2.—EFFECT OF AUDIO-VISUAL CONFIGURATION ON THE PERCEPTION OF APPARENT MOVEMENT

Apparatus and Procedure

The general set-up of this experiment was the same as for experiment 1, except that auditory stimuli were also presented by means of an oscillator, and earphones were worn by O. O's task at all times was to signal one of the three responses to the visual stimuli: (1) alternation, (2) movement, (3) simultaneity, as in the previous experiment.

The oscillator supplied a tone of 1000 d.v./sec. whose intensity could be regulated by means of a rheostat. No attempt was made, however, to regulate the intensity exactly for all O's, since the intensity variable was not considered in this experiment. The rheostat was set at a point judged by each O to be "quite loud, but not uncomfortable," and remained at that point throughout the experiment. The temporal configuration of the auditory and visual stimuli was controlled by means of contact discs (Fig. 2), whose relative positions determined the temporal sequence of presentation of the two sets of stimuli. One of the discs alternately closed the left and right light circuits at A and B brushes. The other disc closed the circuit for sound at A′ and B′ brushes, O receiving the tone in both earphones twice during the cycle. The 90° slot permitted changing the relative positions of the brass contact sectors on the perimeters of the two discs, so that the visual and auditory stimuli could be either exactly simultaneous or exactly alternate. The former condition we shall call the simultaneous-sound or SS condition, the latter the alternating-sound or AS condition. The oscillator was disconnected for the no-sound or NS condition. In the SS and NS conditions there was a dark and silent interval between stimuli, ⅓ of the cycle. In the AS condition we have a cycle consisting of

			At 60 ~/min.	*At 120 ~/min.*
(a) right light	—duration	1/6 of cycle	167σ	83σ
(b) dark & silent	interval	1/12 " "	83σ	42σ
(c) sound	—duration	1/6 " "	167σ	83σ
(d) dark & silent	interval	1/12 " "	83σ	42σ
(e) left light	—duration	1/6 " "	167σ	83σ
(f) dark & silent	interval	1/12 " "	83σ	42σ
(g) sound	—duration	1/6 " "	167σ	83σ
(h) dark & silent	interval	1/12 " "	83σ	42σ
		whole cycle	1000σ	500σ

The data were recorded from the shifts in signal as in experiment 1, and are given in terms of the range of cycles-per-minute for apparent movement. A 15-minute practice period preceded the first session. There was a ½-minute rest between trials, and a 5-minute rest in the middle of the session. Introspections were obtained during the rest period and at the end of each session.

Sequence of Trials

The sequence of trials was governed by the consideration that a dynamic approach to psychophysics requires making allowance for the fluctuating nature of most psychophysical functions, a property amply illustrated for the phi function in experiment 1. If we alternate the NS and SS trials, for example, and these alternations happen to coincide with the fluctuations in the function, we may obtain a separation of the two sets of data which is a mere artifact of sequence. Two precautions are therefore necessary: (1) the use of more than one sequence of alternation of the experimental trials, with different subjects; (2) the use of control subjects whose readings are to be broken up into curves just as though they had been taken under two different alternating conditions of stimulation.

In view of these considerations, the two conditions compared for a given graph were presented to some subjects in the ABAB sequence, to others in the AAABBBAAABBB sequence. The second sitting was always the exact reverse of the first. Thus the sequence of trials for two observers in the sound series was as follows (an asc. & desc. series constituting a trial):

J.G.				*D.Y.*			
Session				*Session*			
1	*2*	*3*	*4*	*1*	*2*	*3*	*4*
NS	AS	NS	SS	AS	NS	SS	NS
NS	AS	NS	SS	NS	AS	NS	SS
NS	AS	NS	SS	AS	NS	SS	NS
AS	NS	SS	NS	NS	AS	NS	SS
AS	NS	SS	NS	AS	NS	SS	NS
AS	NS	SS	NS	NS	AS	NS	SS
NS	AS	NS	SS	AS	NS	SS	NS
NS	AS	NS	SS	NS	AS	NS	SS
NS	AS	NS	SS	AS	NS	SS	NS
AS	NS	SS	NS	NS	AS	NS	SS
AS	NS	SS	NS	AS	NS	SS	NS
AS	NS	SS	NS	NS	AS	NS	SS

The first two sessions for each O were used to compare one of the sound conditions with the no-sound or normal condition. The last two sessions were used to compare the other sound condition with the no-sound condition. The interval between sessions was largely dependent on the availability of O's, but the interval between sessions 3 and 4 was always made equal to the interval between session 1 and 2, and the interval between sessions 2 and 3 equal to or longer than the other two intervals.

Ten O's were used in this experiment, as follows:

2 O's with alternating trials (ABAB).
4 O's with 3A–3B sequence.
4 O's using artificial pupils 2 mm. in diameter. 2 of these O's in ABAB sequence, 2 in 3A–3B sequence.

Results

The results of experiment 2 are graphically represented in Figs. 7 and 8. The dividing line in each graph represents a time interval between two experimental sessions, and two such graphs constitute the results for each O. The abscissae refer to the order of trials under each of the two conditions tested: *i.e.,* sound (AS or SS) and no-sound (NS). Thus trial 2 for D.Y. is the second trial for NS as well as the second trial for AS, although they are actually the 3rd and 4th trials respectively, when counted as in experiment 1. The total number of trials is therefore 48, but these are separated into sound and no-sound curves. The sequence of alternation of test conditions indicated at the top of each graph refers to the beginning of the sequence in the first of the two sessions. The second session is, of course, the reverse of the first in sequence of trials (see above). The ordinates represent the ranges of stimulus-cycles-per-min. during which apparent movement was observed. As in experiment 1, these figures represent the mean between an ascending and descending series, the reversals of response being added to the main range. In all cases the broken line ----- represents the range with sound; the continuous line ———— the range without sound. Where ----- is lower than ———— an inhibiting effect of sound on apparent movement is indicated; where it is higher, a facilitating effect is indicated.

There are three factors to be considered in an inspection of the curves: (1) the effect of heteromodal stimulation and the difference in inter-sensory configuration; (2) the difference in the extent of the effect during succeeding sessions; (3) individual differences in the susceptibility to heteromodal stimulation.

Inspecting Fig. 7 for these factors, we observe: (1) The AS curve in general shows an inhibiting effect on the perception of apparent movement, while the SS curve shows a facilitating effect. This is true for these four O's regardless of the sessions in which the sound conditions were maintained. (2) Nevertheless, the extent of the influence was less for the condition tested during the 3rd and 4th trials than for the one tested during the 1st and 2nd. This is true regardless of the condition tested. (3) It is obvious that F.S. was more susceptible to heteromodal stimulation than D.Y., and that S.K. was more susceptible than E.W. The curves for S.K. and E.W. must, of course, be compared by quarters rather than single trials, since the corresponding points on the two curves do not actually correspond in sequence, when the sequence is 3 & 3 instead of 1 & 1. They serve, however, as a check on the possibility of obtaining curve separations which are artifacts of fluctuation, rather than genuine differences due to the influence of heteromodal stimulation. That the differences are genuine is evidenced by the fact that the results for E.W. and S.K. are substantially the same as those for D.Y. and F.S.:—a facilitating effect of simultaneous sound, and an inhibiting one with alternating sound; also a decrease in the extent of either effect when it occurs in the later rather than the earlier sessions. These differences are quantitatively expressed in Table 3, which we shall come to shortly.

The effect of the difference in audio-visual configuration illustrated by Fig. 7 was not universal, however, showing that configuration is not the only factor operating to determine the effect of heteromodal stimulation. In Fig. 8 we see that J.G. and C.K. show the usual inhibitory effect of AS in rather marked degree, but there is no facilitating effect of the SS condition. For J.G. no consistent tendency is visible under the SS condition. In his case the falling off of the influence might be attributed to adaptation, since there is a slight sign of facilitation at the beginning of the 3rd session. C.K., however, continues to show an inhibitory influence under the SS condition. It will also be observed that each session tends to end on a lower level than the preceding one. In his case we can only conclude that a loud tone, regardless of its configuration, had a cumulative inhibitory effect and after-effect on the perception of apparent movement. This, of course, raises the question of the rôle of the intensity of the heteromodal stimulus apart from its configuration with the attended stimulus. This question will be considered in greater detail in the next experiment.

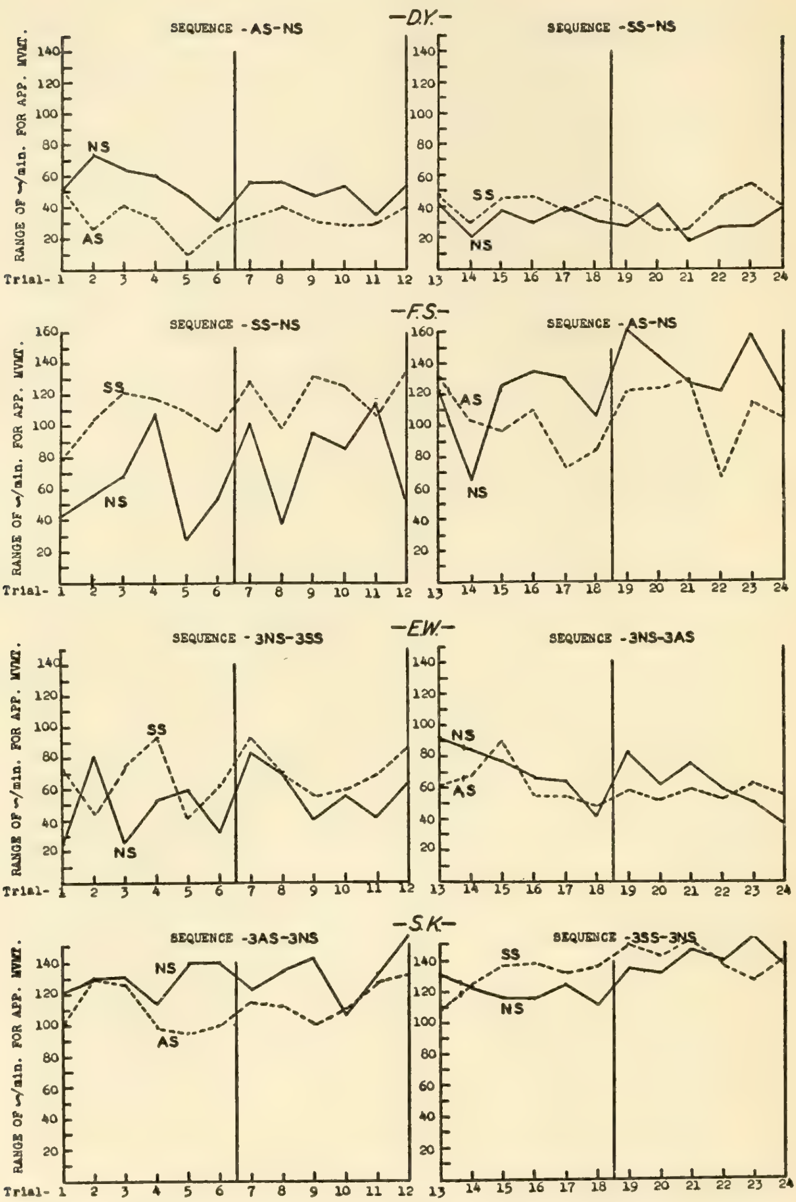

FIG. 7. Effect of simultaneously and alternately presented tones on the range of stimulus frequencies producing apparent visual movement.

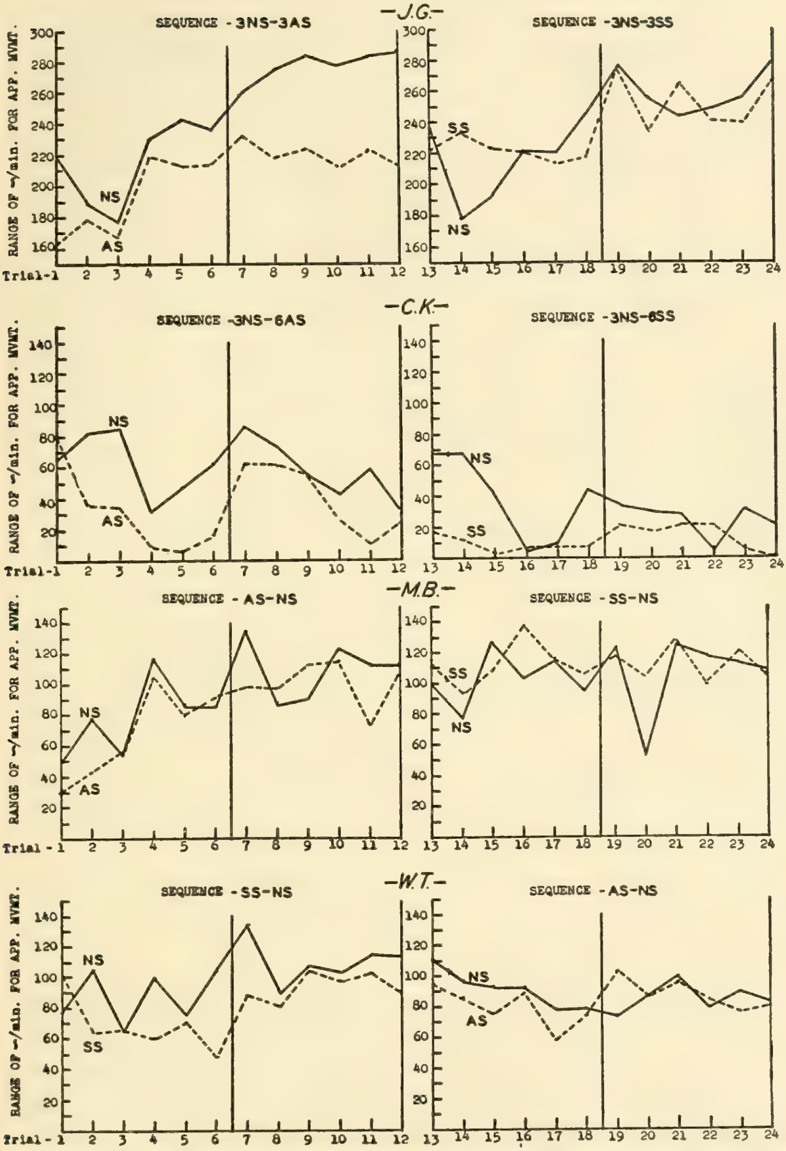

Fig. 8. J.G. and C.K. show absence of facilitating effect of SS. M.B. and W.T. used artificial pupils.

The two O's wearing artificial pupils yield results quite comparable to the foregoing, within the range of normal individual differences. M.B. shows a slight inhibitory effect of AS and a slight facilitating effect of SS, which becomes indifferent toward the end.

W.T. shows the inhibiting effect of sound regardless of configuration, an effect which likewise becomes negligible toward the end, showing the effect of adaptation. Of the other two O's wearing artificial pupils (not shown), one (D.B.) exhibited a fairly consistent inhibiting effect of sound under the AS condition, but no consistent tendency under the SS condition. The other O (D.D.) exhibited no consistent tendencies under either condition.

In Fig. 9 the "control" curves represent the curves of D.S. in experiment 1 broken down into two curves as a control for fluctuation artifacts. The upper set of control curves represent the results

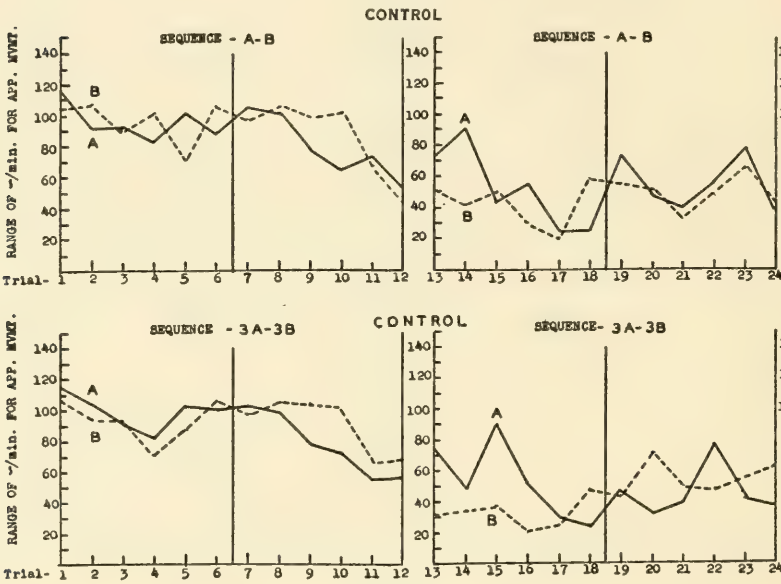

FIG. 9

which would have been obtained if the alternate trials represented two different conditions. The lower set represents the curve broken into the 3–3 sequence of alternation. No consistent tendencies of any sort can be observed, although differences occasionally appear for several consecutive trials.

The results of experiment 2 are quantitatively summarized in Table 3. It will be observed that every one of the 10 O's showed an inhibitory effect of the AS condition, averaging about 17 units or a reduction of 18% of the mean range. The results for the SS condition are bi-modally distributed, with the trend toward facilitation. (The exceptionally high percent value of C.K.'s inhibi-

tory influence distorts the mean percent value.) The factor of adaptation is evident from the lower values obtained in most cases for the later sessions, regardless of configuration or sign.

TABLE 3

Mean Differences between Ranges for Phi with Sound and No-sound

O	Seq.	*Diff. acc. to config.*				*Diff. by sessions*			
		~/min.		*Percent*		*~/min.*		*Percent*	
		AS	*SS*	*AS*	*SS*	*1 & 2*	*3 & 4*	*1 & 2*	*3 & 4*
FS	1 & 1	−22.5*	+42.0*	−18	+60	42.0	22.5	60	18
DY	1 & 1	−17.7*	+ 8.4†	−34	+26	17.7	8.4	34	26
MB	1 & 1	−10.3†	+ 6.6‡	−11	+ 6	10.3	6.6	11	6
WT	1 & 1	−18.1*	− 4.9‡	−25	− 5	4.9	18.1	5	21
CK	3–6–3	−24.5	−21.5	−41	−67	24.5	21.5	41	67
EW	3 & 3	− 6.6	+13.3	−10	+25	13.3	6.6	25	10
SK	3 & 3	−18.3	+ 3.8	−14	+ 3	18.3	3.8	14	3
DB	3 & 3	−13.1	+ 0.2	−10	0	0.2	13.1	0	10
JG	3 & 3	−39.3	− 0.2	−16	0	39.3	0.2	16	0
DD	3 & 3	− 7.9	− 1.8	− 8	− 2	7.9	1.8	8	2
	Mean	−17.8	+ 5.8	−18	0	17.8	10.3	21	16

* Reliability of better than 98 chances in 100.
† Reliability of 95–96 chances in 100.
‡ Unreliable.

We come now to the question of the reliability of the differences obtained. It is obvious that when a psychophysical function fluctuates as markedly as the frequency range for apparent movement, no two sets of data obtained over two experimental sessions under two different conditions are apt to show a reliable difference by the calculation of D/σ_D. Even a clear-cut difference like the difference between the AS and NS values for D.Y. (Fig. 7) yields a critical ratio of only .31 by this method. This is hardly more than a chance difference according to this criterion, yet a glance at the graph is sufficient to indicate that the actual direction of the difference is well-nigh infallible. This discrepancy is one of the fallacies imposed by the traditional static approach to psychophysics, which tacitly assumes that variations of psychophysical responses are errors of observation or chance variables, and that all data under a given condition may be lumped together to obtain the deviation from the "true" mean. This is an unrealistic treatment of the facts, as the results of experiment 1 have shown. With normal fluctuations, adaptation and fatigue factors constantly operating, any statistical treatment which completely ignores the *sequence* of data in experiments of this sort is worse than useless.

The only valid method of computing the reliability of differences in dynamic psychophysics is to obtain the differences between the

corresponding trials under the two test conditions, compute the mean difference, taking account of sign, and then calculate the reliability of the deviation from zero. This, as Fisher (2) points out, is the same as the critical ratio method corrected for correlation. The paired trials must, indeed, be regarded as correlated by virtue of their similar positions in the sequence of their respective curves, and their proximity in time. This applies, of course, only to the data obtained in single alternation (ABAB). We know of no valid method for computing the reliability of the differences obtained in the 3–3 sequence of alternation. The reliability of differences by Fisher's "*t* test" is therefore given for only four of the O's in Table 3. Ninety-five chances out of 100 is usually regarded as reliable by this criterion.

Summary

The effect of concurrent auditory stimulation on the phi function was tested, again using the range of stimulus-frequencies for apparent movement as a measure of the function. A loud tone of 1000 d.v./sec. was presented simultaneously with the lights (SS condition) and alternately (AS condition), the sound trials alternating with no-sound trials (NS condition), to 10 O's, 4 of whom used artificial pupils. The following results were obtained, demonstrating the factor of inter-sensory configuration as one of the dynamic variables of a psychophysical system:

1. Every O showed an inhibiting effect of AS, with a mean reduction of about 18 percent of the range of frequencies for apparent movement.

2. Five O's showed a facilitating effect for the SS condition, 2 an inhibiting effect, and 3 a negligible difference. The bi-modal distribution shows the operation of factors antagonistic to facilitation, which will be discussed in the next experiment.

3. The differences obtained are not artifacts of the pupillary response to sound, since differences were also obtained with O's using artificial pupils.

4. The differences obtained are not artifacts of the alternation of trials in a fluctuating psychophysical function, as shown when different sequences of alternation and control O's are used.

5. There are considerable individual differences in susceptibility to heteromodal stimulation, the differences in range with sound varying from about 0 to 60 percent of the range without sound.

6. There is a tendency toward adaptation to the heteromodal influence, 8 out of 10 O's giving substantially smaller differences on the last two sessions than for the first two, regardless of configuration.

CHAPTER IV

EXPERIMENT 3.—EFFECT OF SIMULTANEOUS SHOCK ON THE LOWER FREQUENCY THRESHOLD FOR APPARENT MOVEMENT

Apparatus and Procedure

The general set-up for this experiment was the same as for experiment 2, except that electric shock was used as the concurrent stimulus in place of sound. A Harvard Inductorium replaced the oscillator and a specially designed grid replaced the earphones. This grid was designed and wired so that the left and right hands could be stimulated alternately in synchronization with the left and right lights seen in the window of the phi-phenomenon apparatus. The intensity of shock could also be controlled,—at least well enough to leave no doubt about the distinction between "mild" and "intense" shock. In this way the factors of *spatial shift* and *intensity difference* were introduced,—factors lacking in the previous experiment.

The procedure was modified somewhat to facilitate the taking of data with as little demand on the O's time and forbearance as possible. The lower frequency threshold was used as a measure of the phi function in this experiment, because it reduced the time required for each trial by about one-half, thus reducing the complications arising from prolonged faradic stimulation on one trial, and making possible the completion of the whole series of 24 paired trials in one session of less than two hours, rather than four one-hour sessions. The use of lower threshold values rather than the range between thresholds was also demanded by the inability of O to signal with his hands as in experiment 2. O signalled instead with his feet, the signal board being placed on the floor under the table. Tapping the extreme left key with the left foot indicated alternation; the extreme right key with the right foot, movement. A series of rapid taps with either foot was the emergency signal (rarely used). The mean between readings obtained at the shift from alternation to movement in the ascending series, and from movement to alternation in the descending series constituted the threshold value for a given trial. There was a rest of about 15 sec. between trials, and a 5-min. rest in the middle of the session. O's were given a 10-min. practice period in semi-darkness at the beginning, including at least one trial with shock. For mild shock the setting of the inductorium was left at a point where O agreed that it was "just comfortable"

during the preliminary trials. If intense shock was to be used, the inductorium was set at a point which gave O as intense a shock as he could withstand without pain.

O was told that the shock was synchronized with the lights, but that his task was merely to report as accurately as possible when the shift from alternation to phi and from phi to alternation occurred. Paper towels were left on the table for O to wipe the perspiration from his hands between trials, whenever he felt it necessary. O's hands were kept on the grid during all trials, even those without shock. He was told in advance, however, what the sequence of alternation would be (1&1 or 3&3), so that he could tell whether the apparatus was functioning properly.

Six O's were used in this experiment, as follows:

2 O's comparing mild electric shock (ME) and no shock (NE).
2 O's comparing mild shock and no shock, wearing artificial pupils.
2 O's comparing mild shock and intense shock with no shock.

Four of the O's had served in previous experiments, thus allowing comparison with their previous results as controls.

RESULTS

The results of experiment 3 are represented in Fig. 10. The movement-alternation threshold is expressed in cycles-per-min. of stimulation along the left axis of ordinates, and the values are calculated and plotted in terms of these units. For the sake of comparison the equivalent values in units of .001 sec. of time-interval between successive light-flashes or shocks ($\frac{1}{3}$ of cycle) are given along a parallel axis at the extreme right. It will be observed that $\sigma_{\text{int.}}$ bears an inverse geometric relationship to $\sim$/min., so that the graphs would present different appearance if plotted arithmetically in units of σ, and the values (mean between ascending and descending series) would be slightly higher in some cases than their present equivalent of $\sim$/min. values. However, the direction of the differences would be the same, and that is our chief concern here.

It will be observed that in almost all cases mild electric shock applied to the left and right hands alternately in synchronization with the left and right lights lowers the frequency threshold for apparent movement or increases the time-interval threshold. In other words, the mild synchronized cutaneous stimulus facilitates the perception of apparent visual movement, in much the same manner as synchronous sound (SS) facilitated it in experiment 2. Intense shock, however, even though synchronized with the visual stimuli,

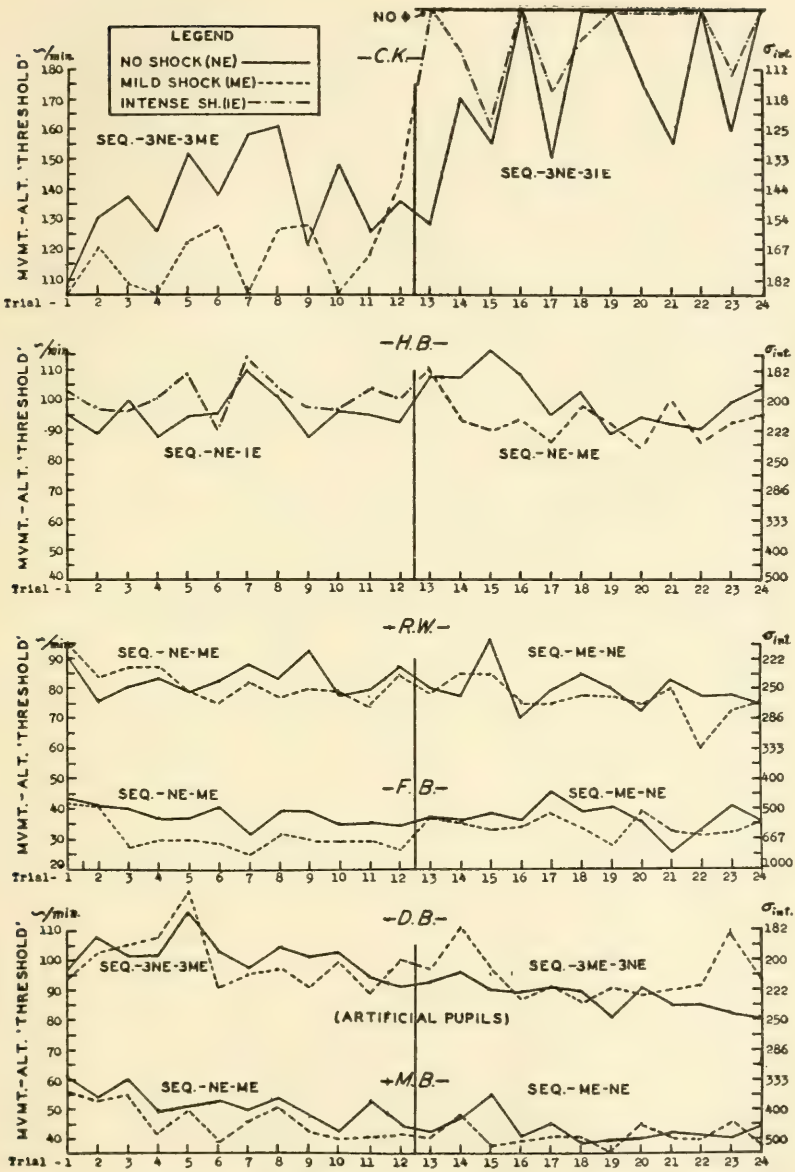

FIG. 10. Effect of mild and intense simultaneous shock on the movement-alternation threshold.

inhibits apparent movement, as we may see in the upper half of Fig. 10. In the case of C.K. we observe that whereas there is a distinct facilitation of apparent movement in the ME or mild electric shock curve, there is a sudden and violent reversal of the effect when

the shock is intensified. So much so, in fact, that on many trials with intense shock no apparent movement at all is observed, so that an arbitrary "ceiling" must be placed above the threshold values at 200 ~/min. This value is selected because it is slightly higher than the highest value otherwise obtained for the threshold, and is approximately the lowest value at which a shift to simultaneity occurred (no signal at all represented simultaneity with this O). All values plotted at the "no ϕ" level represent the complete absence of apparent movement on those trials, both ascending and descending, and values near that level indicate that movement was absent on either the ascending or the descending series of the trial, giving a mean near 200. The sudden rise in the NE curve during the second half of the session *after the first 3 trials* indicates that the inhibitory effect was pro-active as well as concurrent. If we compare C.K.'s results here with his results in the previous experiment (Fig. 8) we may conclude that any intense heteromodal stimulus will inhibit apparent movement, at least for this O, regardless of configuration. H.B. illustrates very clearly the effect of intensity of the heteromodal stimulus, even though his results are not as extreme as those of C.K. in units of ~/min. There is a distinct inhibition of apparent movement with intense shock, and a distinct facilitation wth mild shock.

The introspective reports of these O's illustrate the validity of their results and their essential naivete with respect to the main factors tested in this experiment. C.K. reported at the end of the session: "I couldn't seem to see much movement toward the end. I kept watching for it, but it just wouldn't come, and I was even a little annoyed about it." H.B. reported "Sometimes I depended on rhythmic shock to verify visual impression. . . . Couldn't tell any effect of shock on movement."

Adaptation effects are noticeable in the lower half of Fig. 10, which gives the results comparing ME and NE. R.W., F.B., and M.B. show a fairly consistent facilitating effect, or lowering of the frequency threshold, after a brief period of adaptation to shock, which requires 2 to 5 trials after the preliminary trial. In other words, for the first few trials the effect is apt to be that of a more intense shock. During these adaptation trials there is a negligible or an inhibitory effect, and another brief adaptation period is apt to be required after the 10-min. rest period in the middle of the session. Adaptation to the effect of any shock toward the end of the session is clearly evident in M.B. and to some extent in R.W.

and F.B., where the effect of shock becomes either irregular or negligible. This is also consistent with the results obtained for sound in experiment 2, where the differences obtained during the last two sessions were smaller than for the first two, regardless of configuration.

Individual differences are likewise apparent. D.B. shows no consistent effect of ME, which agrees with the results obtained for him in experiment 2 under the SS condition; while M.B. showed appreciable differences in both experiments, using artificial pupils, which were comparable to results obtained from O's without artificial pupils. This is satisfactory evidence that individual differences constitute an important factor in our results, but the pupillary response does not. Consistent individual differences in susceptibility to heteromodal influence using various modalities have likewise been demonstrated by Hartmann.

An interesting case of what might be called *induced delta movement* was accidentally obtained with M.B. He reported that during some trials the shock was much more intense in the left hand than in the right. This might easily have occurred from perspiration or imperfect contact. During these trials the *movement was much more pronounced* from right to left, and much faster in that direction. Although a psychology student, M.B. had been completely unaware of the phenomenon of delta movement, all the more so of the possibility of *induced delta movement.* Since M.B. was using artificial pupils, this cannot be explained as an artifact of the pupillary response to shock, but is rather a striking example of *inter-sensory Gestalten.* It agrees, incidentally, with results obtained by Zietz & Werner with accented auditory rhythms.

Summary

An attempt was made in this experiment to determine what factors caused inhibition of the phi function with a synchronized intermodal configuration, when the usual effect for this relationship was a facilitating one, as well as to demonstrate heteromodal influence of a stimulus other than sound. For this purpose electric shock was used as the stimulus and the attributes of the stimulus introduced as the variables while internodal configuration was kept constant (simultaneous). Mild and intense shocks were administered to the left and right hand in synchronization with the lights of the phi-phenomenon apparatus. The following results were obtained.

1. Mild synchronous shock generally lowers the frequency threshold for apparent movement,—a facilitating effect.

2. Intense synchronous shock raises the threshold for apparent movement,—an inhibitory effect.

3. There are the usual individual differences in susceptibility to heteromodal influence, and some indication that those less susceptible in one modality are also less susceptible in another.

4. Adaptation to the effect of mild shock at the end of a long session is indicated.

5. A case of heteromodally *induced delta movement* (difference in direction or emphasis of movement) is reported.

CHAPTER V

GENERAL DISCUSSION

The purpose of the foregoing series of experiments was to investigate factors other than the dimensions of the "adequate" stimulus which determine or modify perceptual responses in general and the phi phenomenon in particular. The factors demonstrated on the basis of quantitative data may be grouped into two categories: (a) interaction of excitations,—in this case heteromodal excitations; (b) extra-stimulus variables as manifested by practice and fatigue effects, mental set, ambiguity, fluctuations, etc. We shall discuss the second group of variables first (*cf.* experiment 1).

Extra-Stimulus Variables

The fluctuating nature of the function means that exactly the same conditions of stimulation may result in apparent movement on one trial and alternation or simultaneity on the next, and vice versa. The cause for such fluctuations when all stimulus conditions remain constant is still a matter of speculation. The tendency to dispose of them as errors of judgment or imperfection of technique is generally discredited, and certainly would not apply to the extremely variable responses shown in experiment 1. Involuntary fluctuations of attitude and fixation may account for some of this, as Wertheimer's work suggests. An important rôle is probably also played by the fluctuation of metabolic processes in the receptors and centers. The principle of homeostasis militates against any extreme fluctuations of such processes, however, and necessitates the assumption that slight physiological changes may account for wide differences in sensory responses. The relative magnitudes of physiological and sensory changes need not disturb us, since the latter may be the operational definition of the former. Our knowledge of these relationships is still very meagre, but it is suggested that fluctuations of sensory responses under constant stimulus conditions may eventually be reducible to the two factors of mental set and physiological (metabolic) variability.

The ambiguity of perceptual organization resulting in the reversibility of movement and simultaneity might be disposed of as a special case of the fluctuation of psychophysical functions if it were not for the fact that it is subject in some degree to voluntary control. Furthermore, we are not dealing with a fluctuation of *sensi-*

tivity, as is the case in Thorne's study (6), for example, but a variability of *perceptual organization.* One may speak of receptors as more sensitive to light at one moment than the next, but a change in the *meaning* or *context* of an identical stimulus is another matter. It is possible that the physiological processes involved in perceptual organization are subject to fatigue and fluctuation in much the same manner as the processes involved in the sensitivity to a light stimulus of minimal intensity, with the consequent facilitation of first one and then another type of organization. Nevertheless, we still have the troublesome problem of the apparent "voluntary" control of reversal to contend with, and would have to reconcile this datum to physiological facilitation. In any event, until more is known about the underlying processes, we may regard ambiguity as distinct from fluctuation of sensitivity, or from the fluctuation of the entire function described above.

Progressive changes such as practice and fatigue effects are aspects of the factor of adaptation which pervades all organic responses. Whether a given increase or decrease in the numerical value assigned to a sensation or percept in a psychophysical experiment is to be regarded as positive or negative adaptation, or fatigue or practice effect, depends on the definition of adaptation or efficiency. If the augmentation of the observation of apparent movement is regarded as the function to be practiced, then an increase in the range of frequencies (or distances or intensities) over which it may be observed is a practice effect, and a decrease a fatigue effect, or an increase and decrease in efficiency respectively. If, however, we apply the criterion of accuracy of reproduction of stimulus conditions in consciousness, then the reverse is true. In this study, being concerned with the perception of apparent movement as the function to be studied, we have taken the former point of view.

The tendency for the range of frequencies to increase during the first two or three hours of repeated stimulation with a decline in the fourth indicates the probable concurrent operation of practice and fatigue effects even in perceptual processes. It is possible that the same basic laws of exercise and fatigue underlie both sensory and motor performance. In any event, the factor of progressive or cumulative modification is a vital one in stimulus-response relationships, and one which is not accounted for by the traditional dimensions of static psychophysics. It is evident that we must consider not only the dimensions of the stimulus, but the recency and frequency of previous stimulation.

The effect of previous experience may also manifest itself in mental set. The perseveratory and anticipatory sets illustrated in Fig. 6 are due to immediate or more remote past experience. It is interesting to note that the same kind and amount of previous stimulation may produce entirely different effects on attitude or set. Suggestion or motivation of any kind may also affect attitude, as is well known, and attitude will in turn modify perception to some extent. It is evident that D.S. was motivated to adopt an actively discriminating attitude, as revealed by her introspections, and this may account not only for the anticipatory set, which is unusual, but also for the negative effect of practice on the function, which is also unusual for non-consecutive sessions (Fig. 4). This would be consistent with De Silva's results on the effect of attitudes, as are the previously mentioned results for repeated stimulation during a long session.

Though very little may be known of the mechanisms involved in these extra-stimulus variables, there can be no doubt of their importance in the dynamic psychophysics of perception.

Interaction

The factor of interaction of excitations, besides being more susceptible to experimental control, or at least description in stimulus terms, lends itself more readily to physiological speculation.

Köhler's cortical hypothesis for the phenomenon of apparent movement postulates a column of electrical lines of force irradiating from the first-stimulated area and moving across to a position determined by the second-stimulated area. The "induced current" between these two regions of high potential constitutes the basis for the apparent movement between the two areas. Accepting such an hypothesis for argument's sake, our results seem to show an inhibition or facilitation of this induction by means of heteromodal stimulation. When the heteromodal stimulus occurs exactly between visual stimulations, there is an inhibition of this process. In other words, the occurrence of extraneous excitation during the interval when the "shift" takes place deflects or dissipates the energy required from the visual cortical areas, somewhat after the fashion of the drainage hypothesis. On the other hand, when the heteromodal excitation,—provided it is not too intense,—occurs simultaneously with the visual excitation, the effect is such that there is a facilitation of the irradiation of Köhler's lines of force, as though a period of super-excitability for this conduction set in immediately after the

dissipating effect of the heteromodal stimulus. If the heteromodal stimulus and excitation is too intense, however, the inhibitory period or dissipating effect on the lines of force is prolonged so that it is effective during the crucial interval regardless of whether the heteromodal stimulus itself is present between the two visual stimulations. Thus intense simultaneous shock and sometimes loud simultaneous sound inhibited movement. The bi-modal distribution and generally smaller differences under the SS condition (Table 3) indicate that both factors,—temporal relationship and intensity,—may have been acting in antagonism, the net effect being dependent upon the duration of the dissipating effect of the heteromodal excitation and the latency of recovery from this effect, or super-excitability. An interesting check on this hypothetical explanation would be to test the effects of heteromodal stimulation at different intervals of interpolation between the visual stimuli. Our AS condition used only the exactly middle position of sound interpolation, and the simultaneous stimuli were exactly simultaneous. These may not be the optimum conditions for inhibition and facilitation, and the effect may not be the same at both extremes of the range for movement because of the difference in time interval.

Formulations

Returning now to the Korte-Koffka formulations, we have seen that the statement $\phi_{sim.} > \phi_{opt.} > \phi_{suc.}$ is approximately true if interpreted as in Fig. 1. As far as the psychophysical approach to perceptual processes is concerned, it illustrates the important fact that *Gestaltqualitäten* are not automatically inducible from the dimensions of stimulation, but require special definition. Apart from this, we have emphasized the inadequacy of the dimensions of the "adequate" stimulus in determining the function itself, as Koffka well recognized. A more adequate statement of the function might be

$$\phi = f\ [\text{visual}\ \frac{d}{i,\,t},\ \text{nonvisual}\ (i, t, \ldots),\ M, E, P, \ldots]$$

wherein the function ϕ depends not only on the dimensions of the visual stimulus, but their relationship to the dimensions of other stimuli, as well as numerous extra-stimulus factors such as mental set, experience, physiological state of the organism, etc.

We should also have to modify our conception of the probable distribution of judgments. In the first place, the ambiguity at the movement-simultaneity threshold would require a distribution of

judgments totalling more than 100 percent of the trials, since the very same t-value may produce both movement and simultaneity on the same trial if more than one stimulus is given. Secondly, some allowance must be made for facilitative and inhibitory factors, such as the extraneous-stimulus and extra-stimulus components in the equation. Under facilitating conditions we might include mild simultaneous heteromodal stimulation, a passive and perseveratory attitude, and practice effects. Inhibiting conditions would include intermittent or intense heteromodal stimulation, certain attitudes, and fatigue effects.

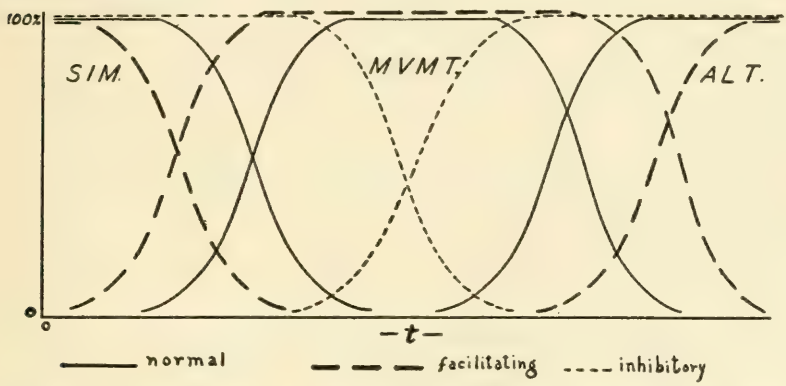

FIG. 11. Distribution of judgments under normal, inhibitory, and facilitating conditions.

Fig. 11 is a schematic representation of the variability of the perceptual response as illustrated in this study. It will be seen that under favorable conditions movement is seen in the large majority of cases over a very wide range of stimulus values, whereas under extremely inhibitory conditions only alternation or simultaneity is seen over the very same range of stimulus values,—facts which are not accountable by the traditional adequate-stimulus dimensions of static psychophysics.

GENERAL SUMMARY

Equations between attributes of sensation and corresponding dimensions of "adequate" stimuli are characterized as static psychophysics. The more dynamic approach required by the formulation of perceptual processes takes cognizance of *Gestaltqualitäten,* the interaction of excitations, and the influence of extra-stimulus factors in determining perceptual responses.

On the basis of quantitative data the following examples of dynamic variability were illustrated in the case of the phi phenomenon:

1. *Momentary and periodic fluctuations* of the function, due, presumably, to normal fluctuations of organic processes as well as of mental set.

2. *Progressive changes,* such as adaptation, practice, and fatigue effects, depending on the recency and frequency of previous stimulation.

3. *Ambiguity* of perceptual organization under certain conditions.

4. *Perseveratory and anticipatory set,* and other illustrations of the general factor of mental set, which may depend on the type and level of immediately preceding or concurrent stimulation, past experience, suggestion, or other motivation.

5. *Inter-sensory inhibition and facilitation,* depending on the attributes of the heteromodal stimuli as well as inter-sensory configuration.

Some methodological and theoretical implications are discussed.

REFERENCES

1. De Silva, H. R. An experimental investigation of the determinants of apparent visual movement. *Amer. J. Psychol.*, 1926, 37, 469–501.
2. Fisher, R. A. *Statistical Methods for Research Workers.* London: Oliver & Boyd, 1936.
3. Hovland, C. I. Apparent movement. *Psychol. Bull.*, 1935, 32, 755–778.
4. Koffka, K. In Bethe, *Handbuch der normalen und pathologischen Physiologie,* XII 2. Berlin: Springer, 1931.
5. Neff, W. A critical investigation of the visual apprehension of movement. *Amer. J. Psychol.*, 1936, 48, 1–42.
6. Thorne, F. C. The psychophysical measurement of the temporal course of visual sensitivity. *Arch. Psychol.*, 1934, No. 170.
7. Wertheimer, M. Experimentelle Studien über das Sehen von Bewegung. *Z. Psychol.*, 1912, 61, 161–265.
8. Zietz, K., and Werner, H. Ueber die dynamische Struktur der Bewegung. *Z. Psychol.*, 1927, 105, 226–249.

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Journal of Genetic Psychology—Provincetown, Mass.; The Journal Press. Subscription $14.00 per annum (2 volumes). 1000 pages annually. Edited by Carl Murchison. Quarterly. Child behavior, animal behavior, and comparative psychology. Founded 1891.

Psychological Review—Ohio State University, Columbus, O.; American Psychological Association, Inc. Subscription $5.50. 540 pages annually. Edited by Herbert S. Langfeld. Bi-monthly. General psychology. Founded 1894.

Psychological Monographs—Ohio State University, Columbus, O.; American Psychological Association, Inc. Subscription $6.00 per volume. 500 pages. Edited by John F. Dashiell. Without fixed dates, each issue one or more researches. Founded 1895.

Psychological Bulletin—Ohio State University, Columbus, O.; American Psychological Association, Inc. Subscription $7.00. 665 pages annually. Edited by John A. McGeoch. Monthly (10 numbers). Psychological literature. Founded 1904.

Archives of Psychology—New York, N. Y.; Columbia University. Subscription $6.00 per volume. 500 pages. Edited by R. S. Woodworth. Without fixed dates, each number a single experimental study. Founded 1906.

Journal of Abnormal and Social Psychology—Ohio State University, Columbus, O.; American Psychological Association, Inc. Subscription $5.00. 560 pages annually. Edited by Gordon W. Allport. Quarterly. Founded 1906.

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Journal of Experimental Psychology—Ohio State University, Columbus O.; American Psychological Association, Inc. Subscription $14.00 per annum (2 volume). 1250 pages annually. Edited by Samuel W. Fernberger. Monthly. Founded 1916.

Journal of Applied Psychology—Lancaster, Pa.; The Science Press Printing Co. Subscription $6.00. 600 pages annually. Edited by James P. Porter. Bi-monthly. Founded 1917.

Journal of Comparative Psychology—Baltimore, Md.; Williams & Wilkins Co. Subscription $10.00 per annum (2 volumes). 900 pages annually. Edited by Roy M. Dorcus, Knight Dunlap and Robert M. Yerkes. Bi-monthly. Founded 1921.

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Genetic Psychology Monographs—Provincetown, Mass.; The Journal Press. Subscription $7.00. 500 pages per annum. Edited by Carl Murchison. Bi-monthly. Each number one complete research. Child behavior, animal behavior, and comparative psychology. Founded 1925.

Psychological Abstracts—Ohio University, Columbus, O.; American Psychological Association, Inc. Subscription $7.00. 700 pages annually. Edited by Walter S. Hunter and R. R. Willoughby. Monthly. Abstracts of psychological literature. Founded 1927.

Journal of General Psychology—Provincetown, Mass.; The Journal Press. Subscription $14.00 per annum (2 volumes). 1000 pages annually. Edited by Carl Murchison. Quarterly. Experimental, theoretical, clinical and historical psychology. Founded 1927.

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Character and Personality—Durham, N. C.; Duke University Press. Subscription $2.00. 360 pages annually. Edited by Karl Zener. Quarterly. Founded 1932.

Journal of Psychology—Provincetown, Mass.; The Journal Press. Subscription $14.00 per annum (2 volumes). 800–1200 pages annually. Edited by Carl Murchison. Quarterly. Founded 1936.

Psychometrika—University of Chicago, Ill.; Psychometric Society. Subscription $10.00. 320 pages annually. Edited by L. L. Thurstone and others. Quarterly. Quantitative methods in psychology. Founded 1936.

Psychological Record—Bloomington, Ind.; Principia Press. Subscription $4.00. 500 pages annually. Edited by J. R. Kantor and C. M. Louttit. Without fixed dates, each number a single research. General psychology. Founded 1937.

Journal of Consulting Psychology—Colorado Springs, Colorado; The Dintan Printing Co. Subscription $2.00. 200 pages annually. Edited by J. R. Symonds. Bi-monthly. Founded 1937.